11. Cost and Emission Reduction Analysis of HFC and PFC Emissions from Fire Extinguishing in the United States

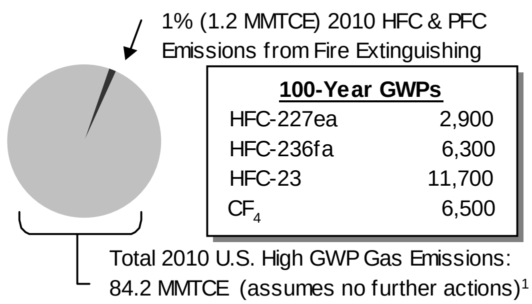
11.1 Introduction

The principal greenhouse gases emitted from fire extinguishing systems are hydrofluorocarbons (HFC-227ea, HFC-236fa, HFC-23) and perfluoromethane (CF_4). These gases have 100-year global warming potentials (GWPs) that are several thousand times the GWP for carbon dioxide (see Exhibit 11.1). Emissions of these gases from fire extinguishing systems in the United States are forecast to reach over one MMTCE in 2010 under a business-as-usual scenario if further reduction efforts are not made (see Exhibit 11.1).[1]

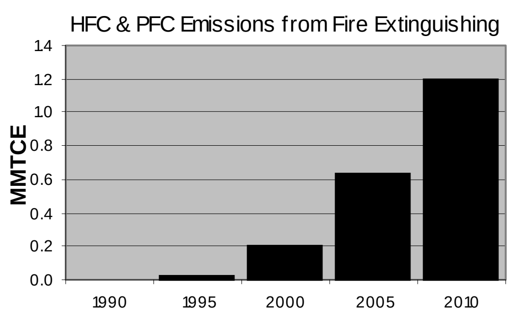
These high GWP gases are substitutes for halons, Class I ozone-depleting substances (ODS) that have been widely used in fire-extinguishing applications in the United States. Although halons were produced in much lower volumes than other ODS, they have extremely high ozone depletion potentials (ODP) due to the presence of bromine, which reacts more strongly with ozone than chlorine. Halons are used in fire suppression and explosion protection applications because they are electrically non-conductive, dissipate rapidly without residue, are safe for limited human exposure, and are extremely efficient in extinguishing most types of fires (EPA, 1994).

Halon applications in the United States can be divided into two categories: (1) portable fire extinguishers (streaming) that originally used Halon 1211, and (2) total flooding applications that originally used Halon 1301 (March Consulting Group, 1998 and 1999). SF_6 was used in fire extinguishing systems for testing purposes to a small extent by the Navy, but for the most part is no longer used in any capacity in the fire protection sector.

Exhibit 11.1: U.S. Historical and Baseline HFC and PFC Emissions from Fire Extinguishing



100-Year GWPs	
HFC-227ea	2,900
HFC-236fa	6,300
HFC-23	11,700
CF_4	6,500



Portable fire extinguishers are most frequently used in offices, manufacturing and retail facilities, aerospace/marine applications, and homes. With the implementation of the halon production phaseout in

[1] An explanation of the business-as-usual scenario under which baseline emissions are estimated appears in the Introduction to the Report.

the UNITED STATES, about 80 percent[2] of new portable fire extinguishing units are now manufactured with non-ODP/low-GWP alternatives such as dry powder, carbon dioxide, or water in place of Halon 1211. HCFC blends are also used. Market penetration of HFCs in this sector has been limited, and is unlikely to grow except in certain specialized applications (e.g., marine, aviation, and military applications). PFCs have had a very small penetration in the portable fire extinguisher market. By 2010, only two HFCs, HFC-236fa and HFC-227ea, are expected to be used to a limited extent as replacements in small segments of the portable extinguishing sector.

Total flooding systems are usually used for fixed-site systems to protect a variety of spaces, including:

- electronic and telecommunications equipment, such as tape storage areas, computer facilities, telecommunications gear, medical facilities, control rooms in nuclear power plants, and air traffic control towers;
- military applications, including aviation engine nacelles and dry bays, naval engine compartments and flammable liquid storage areas, and engine compartments and occupied crew spaces of ground combat vehicles;
- oil production facilities;
- flammable liquid storage areas;
- engine nacelles and cargo bays of commercial aircraft;
- cultural institutions and museums;
- records storage areas;
- bank vaults;
- warehouses; and
- special facilities, such as research laboratories and high-security military facilities.

Halon 1301 was historically used in applications where human exposure to the agent was likely, because the fire extinguishing concentration was safe for limited, acute human exposures. HFC-227ea is the primary halocarbon that has replaced Halon 1301 in these applications. Inert gas systems that contain varying amounts of nitrogen, argon, and carbon dioxide are also being used in these applications. Other HFCs, such as HFC-23 and HFC-236fa, that are also safe for limited, acute human exposures, are being used in smaller amounts due to environmental, technical, and economic reasons. Use of HFC-125 has been limited to normally non-occupied specialty applications, such as aviation engine nacelles. New methods to determine safe concentrations for limited, acute human exposure have recently been adopted in the National Fire Protection Association (NFPA) 2001 Standard on Clean Agent Fire Extinguishing Systems, and may allow the use of HFC-125 and other agents in additional applications. A very small number of telecommunications facilities are also using PFCs. A variety of non-ODP/non-GWP alternative technologies are also being used in various applications that formerly used Halon 1301. Not-in-kind alternative technologies are also available, including powdered aerosols, water sprinklers, water mist systems, and foams.

[2] Estimated from EPA's Vintaging Model.

11.2 Historical and Baseline HFC and PFC Emission Estimates

EPA uses a detailed Vintaging Model of ODS-containing equipment and products to estimate the use and emissions of various ODS substitutes, including HFCs and PFCs. (See Appendix A for a full description of the Vintaging Model.) Historic HFC and PFC emissions from both portable fire extinguishing and total flooding systems totaled 0.02 MMTCE in 1995 (Exhibit 11.2). Baseline estimates for the years 2000, 2005, and 2010 shown in Exhibit 11.3 are also based on estimates from the Vintaging Model. These estimates do not distinguish between emissions from servicing, leaks, accidental/false discharges, or intentioned discharges to extinguish fires. There are several regulatory programs (e.g., Significant New Alternatives Policy (SNAP) program) in place that limit the use of ODS substitutes in some applications, which have resulted in reductions in ODS substitute emissions. These reductions are incorporated in the baseline estimates. The cost analysis presented here evaluates the cost of reducing emissions from this baseline.

Exhibit 11.2 Historical U.S. HFC and PFC Emissions from Fire Extinguishers (1990-1999)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Emissions (MMTCE)	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.06	0.10	0.15

Source: EPA, 2000 (for 1990-1998) and EPA estimates (for 1999).
Notes:
Emissions are not broken down by chemical to avoid disclosure of confidential business information.
Conversion to MMTCE is based on the GWPs listed in the Introduction to this report.

Exhibit 11.3: Baseline U.S. HFC and PFC Emissions from Fire Extinguishers (2000-2010)

	2000	2005	2010
Emissions (MMTCE)	0.20	0.64	1.20

Notes:
Emissions are not broken down by chemical to avoid disclosure of confidential business information.
Conversion to MMTCE is based on the GWPs listed in the Introduction to this report.
Approximately 80 percent of total emissions in 2010 are attributable to total flooding applications, whereas 20 percent are attributable to portable system applications.
Forecast emissions are based on a business-as-usual scenario, assuming no further action.

11.3 HFC and PFC Emission Reduction Opportunities

The existing options for reducing HFC and PFC emissions from the fire protection sector include the use of alternative fire protection agents and the use of alternative technologies and practices. The remainder of this section discusses use options.

Use of Alternative Fire Protection Agents

Inert gases and water mist systems that provide an equivalent level of both fire protection and life safety/health protection could be considered as alternatives to some HFC use in total flooding applications. Carbon dioxide in total flooding systems has been in use for many years. Due to the lethal concentrations at which carbon dioxide is required for use as a fire extinguishing agent (at least 34 percent), safety standards regulate its use in occupied areas. The NFPA 12 Standard requires safeguards such as predischarge alarms and time delays to ensure prompt evacuation prior to discharge, prevent entry into areas where carbon dioxide has been discharged, and provide means for prompt rescue of any trapped personnel. Likewise, the International Maritime Organization's Safety of Life at Sea (SOLAS) standard does not prohibit the use of carbon dioxide in normally occupied areas, but calls for the use of suitable alarms and mandates against the use of automatic release of the fire-extinguishing medium, as specified in EPA (2000). According to the NFPA, some of the types of hazards and equipment that carbon dioxide systems protect are "flammable liquid materials; electrical hazards, such as transformers, switches, circuit breakers, rotating equipment, and electronic equipment; engines utilizing gasoline and other flammable liquid fuels; ordinary combustibles, such as paper, wood, and textiles; and hazardous solids" (NFPA 12). Because carbon dioxide systems are more economical than the use of HFCs, a small niche market has been carved for carbon dioxide in the total flooding sector. While carbon dioxide systems will continue to be used in narrow use flooding applications, where permitted by regulatory, liability and safety/health standpoints, it is assumed that carbon dioxide will not displace any use of HFCs in this sector.

Use of Alternative Technologies and Practices

In addition to installing alternative systems, improved fire prevention technologies may be used to reduce HFC and PFC emissions. Some oil and gas processing facilities in Alaska's Arctic North Slope region have begun installing early warning smoke detection, infrared cameras (to better distinguish real fires from false alarms), and other technologies that can either reduce the amount of agent discharged to prevent a fire or prevent a discharge altogether. There may also be opportunities to reduce emissions from portable fire extinguishers during training procedures, by using simulators or training videos rather than actual system discharges.

Available alternatives to reduce emissions in the fire protection sector may not be technically or economically viable for all end use applications. For example, military applications often have very specialized needs (due in part to issues of national security and the potential for combat situations) that do not exist in other end-use applications. Similarly, applications that are space and/or weight constrained, such as marine and aviation applications, may be more limited in their choice of alternative agents. Electronic and telecommunication applications which represent the largest use of HFCs in the total flooding sector, offer the greatest opportunities to consider potential alternatives, albeit with significant potential economic and technical penalties.

11.4 Cost Analysis

This cost analysis focuses on total flooding applications. Based on projections from the Vintaging Model, these applications will account for about three-quarters of the weighted high GWP gas emissions from fire extinguishing systems in 2010. Outlined below are two potential options for reducing emissions of high GWP gases from total flooding systems.

The first option is the use of zero GWP inert gas systems. Costs are determined relative to typical HFC-227ea systems, as they predominate in the HFC market. Inert gas systems would be suitable in the electronics/telecommunications applications and other Class A surface fire hazards that represent an estimated 95 percent of the total flooding sector. It was estimated that inert gas systems could displace up to 45 percent of HFC use. Installation costs for inert gases were assumed to be ten percent higher than for HFCs on an equivalent volume of protected space basis. Inert gas systems require significantly more storage space for agent cylinders, since a greater amount of inert gas is needed per unit volume of protected space, as compared to HFC-227ea. The one-time cost to build or rent additional space (assumed to be $150 per square foot) and annual heating and cooling costs (assumed to be $8 per square foot) are included. As shown below, this option could reduce total emissions from the fire extinguishing sector (including streaming) by 25 percent.

The second option is the use of water mist systems. These systems could provide equivalent fire protection and life safety/health protection for Class B fuel hazards where low temperature freezing is not a concern. Installation costs for water mist systems are estimated to be 75 percent of the cost of an HFC system, representing large cost savings. Because of the significant cost savings, it is estimated that water mist systems could replace up to five percent of the total flooding applications of HFCs, which is the estimated percent of Class B applications in the total flooding market. As shown in Exhibit 11.4, water mist systems could reduce total emissions in the fire extinguishing sector by three percent.

The cost analyses were performed for four- and eight-percent discount rates, both with a ten-year project lifetime. Exhibit 11.4 summarizes HFC emission reductions by cost per metric ton of carbon equivalent (TCE). As shown, 27 percent of total flooding emission reductions from the baseline can be achieved in 2010.

Exhibit 11.4: Emission Reductions and Cost in 2010

Option	Break-Even Cost ($/TCE) Discount Rate		Incremental Reductions		Sum of Reductions	
	4%	8%	MMTCE	Percent	MMTCE	Percent
Water Mist Systems	(16.19)	(19.42)	0.03	3%	0.03	3%
Inert Gas Systems	53.86	61.44	0.29	25%	0.33	27%

Note:
2010 baseline emissions from the fire extinguishing sector equal 1.2 MMTCE.
Conversion to MMTCE is based on the GWPs listed in the Introduction to the Report.
Sums might not add to total due to rounding.

11.5 References

EPA. 1994. SNAP Technical Background Document: Risk Screen on the Use of Substitutes for Class I Ozone-Depleting Substances: Fire Suppression and Explosion Protection (Halon Substitutes).

EPA. 2000. *Carbon Dioxide as a Fire Suppressant: Examining the Risks*. Office of Air and Radiation, U.S. Environmental Protection Agency, Washington, DC. EPA430-R-00-002.

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March Consulting Group. 1998. *Opportunities to Minimize Emissions of Hydrofluorocarbons (HFCs) from the European Union.* Final Report. Prepared by March Consulting Group, UK.

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